DOCUMENT RESUME

ED 036 204 EM 007 848

AUTHOR	FELDHUSEN, JOHN H.; LORTON, PAUL, JR.
TITLE	A POSITION PAPER ON CAI RESEARCH AND DEVELOPMENT. A SERIES TWO PAPER FROM ERIC AT STANFORD.
INSTITUTION	STANFORD UNIV., CALIF. ERIC CLEARINGHOUSE ON EDUCATIONAL MEDIA AND TECHNOLOGY.
SPONS AGENCY	OFFICE OF EDUCATION (DHEW), WASHINGTON, D.C.
PUB DATE	FEB 70
NOTE	33P.
EDRS PRICE	EDRS PRICE MF-$0.25 HC-$1.75
DESCRIPTORS	CARRELS, *COMPUTER ASSISTED INSTRUCTION, DISPLAY SYSTEMS, *EDUCATIONAL DEVELOPMENT, *EDUCATIONAL RESEARCH, MODELS, PROGRAMING LANGUAGES, TIME SHARING

ABSTRACT

AFTER A CRITICAL REVIEW OF THE PAPERS ON COMPUTER-ASSISTED INSTRUCTION (CAI) OF SEVERAL PROMINENT EDUCATORS, RECOMMENDATIONS ARE PROFFERED FOR CAI SYSTEMS IMPROVEMENTS PRIOR TO NEW RESEARCH. THESE INCLUDE REPLACING THE TYPED MESSAGE WITH AN INEXPENSIVE CATHODE RAY TUBE, DEVELOPING THE STUDENT INTERFACE AS AN EFFICIENT AND PLEASANT CARREL WHICH AFFORDS ACCESS TO SEVERAL MEDIA, MAKING AVAILABLE TIME SHARING SERVICE AND TERMINALS TO AVOID ARTIFICIAL CONSTRAINTS ON INSTRUCTION, DEVELOPING ONE SET OF PROGRAMING LANGUAGES FOR SEVERAL MODES OF INSTRUCTION AND FOR THE AUTHOR MODE, AND DEVELOPING SOME LENGTHY COURSES TO SERVE AS VEHICLES OF RESEARCH AND AS MODELS OF CAI POTENTIAL. CONCLUDING THE PAPER ARE ABSTRACTS OF THE PAPERS BY ZINN, ROGERS, KANNER, STOLUROW, OETTINGER AND MARKS, KOPSTEIN AND SEIDEL, RANDALL AND BLASCHKE, AND GENERAL LEARNING CORPORATION. THESE ABSTRACTS WERE REVIEWED AT THE BEGINNING OF THIS PAPER. (AUTHOR/SP)

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A POSITION PAPER ON CAI RESEARCH AND DEVELOPMENT

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With Abstracts of Selected CAI Papers
By Paul Lorton, Jr.

A Series Two Paper from ERIC at Stanford

February 1970

EM007848

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A POSITION PAPER
ON CAI

The Author's Beliefs and Biases

Numerous media or devices may be used to purvey, control, or supplement instruction. Thus, we have BAI (book-assisted instruction), CHAI (chalkboard-assisted instruction), OPAI (overhead projector-assisted instruction), TVAI (television-assisted instruction), and BBAI (bulletin board-assisted instruction) as major devices at present for purveying, controlling, or supplementing instruction.

"Learning" is a general phenomenon which can occur with or without direction or purpose. All by himself a child may learn how to open a door or ride a bike. "Instruction" is all the things we do formally with purpose and direction to produce learning. The things we do under the heading of "instruction" include:

1. Holding the learner in the instruction place,
2. Holding the learner's attention,
3. Presenting information to him in an organized and systematic fashion,
4. Engaging the learner in practice activity such as mathematics exercises, concept induction, creative thinking, or problem solving,
5. Testing to see if or what he is learning,
6. Providing feedback which can be used by the learner to judge the adequacy of his performance or to correct his performance, and
7. Providing reinforcement which will "lock in" the learning.

In all instructional situations we strive for retention and transfer. We want the learner to remember worthwhile things and be able to use (or transfer) them in relevant situations.

In all instructional situations there are goals, purposes, or objectives to provide direction. Sometimes they are specified narrowly and behaviorally, sometimes cognitively as mental abilities, sometimes as knowledge to be acquired, and sometimes as broad practical goals of the learner or the society. Whatever the form, they determine the nature and direction of instruction, more or less.

Most instruction depends heavily on verbal and numerical symbols, as in the five examples below:

A. 87
+32

B. Explain assimilation

C. "Read page 27."

D. Needs ⟶ Behavior

E. APOSTROPHE
   1. abbreviation
   2. possession

Example A may be an exercise written on the board by the teacher. Example B is an exercise printed in a book. Example C is a direction spoken by the teacher. Example D is a diagram in a TV presentation. Example E appears on an overhead projector transparency. Some media such as TV, films, and projectors may also be used to present still and moving pictures while others such as records and audio tapes may be used to present sound messages.

Learning is always an individual phenomenon, but instruction can be carried out effectively either individually or in groups. Some commonality of prior knowledge and skill, level of mental ability, and interest seems essential for students who are engaged in a group instructional situation. There is today growing faith on the part of educational theoreticians that individualization of instruction is the *sine qua non* of learning. However, there is precious little evidence from research to support this view. Widespread practice in schools at all levels indicates that much, but not all, instruction can be carried forward in groups.

All schools at all levels provide for much individualization of instruction. These activities include reading in BOOK (basic organization of knowledge), homework, and practice with various equipment or devices.

"BOOK" is the best medium of individualized instruction so far devised. The student may enter at various places or levels, proceed at his own rate, branch by his own choice or under teacher direction, be actively engaged if he does the study exercises or problems, receive some feedback if the answers are given in the back of the book, and be reinforced if he performs well.

CAI (computer-assisted instruction) is a new experimental technique of instruction which is experiencing many infantile growing pains, but which may, thanks to the computer, provide some improvement over BOOK and which may bring about better integration of various media in instruction. The growing pains of CAI are evidenced by

(1) Excessive theoretical speculations which extend to the notion that there will be a theory of CAI,
(2) Unrealistic expectations that CAI will take over the major instructional role in schools,
(3) The poor quality of many CAI instructional programs and of the research-evaluation of the programs, and
(4) A tendency to become overly concerned with computer hardware and systems.

There appear to be some things which CAI will become able to do better than any other media:

(1) Secure, store and process information about the student's performance prior to and/or during instruction to determine subsequent activities in the learning situation
(2) Store large amounts of information and make it available to the learner more rapidly than any other medium,
(3) Provide programed control of several media such as films, slides, TV, and demonstration equipment,
(4) Give the author or teacher an extremely convenient technique for designing and developing a course of instruction, and

(5) Provide a dynamic interaction between student and instructional program not possible with most other media.

CAI developers ought to leave to others the development of theories of instruction. Instead CAI enthusiasts should study and glean what they can from current theories of instruction (Gagné, 1965; Carroll, 1963; Ausubel, 1968; and Bruner, 1966, for example), curriculum revision and development projects (Heath, 1964), current school practice (such as Jackson, 1968, and Stephens, 1967), public pronouncements of influential organizations such as the NEA, hard evaluations of school achievement such as CAPE (Committee on Assessing the Progress of Education, 1968), and educational research (the *Handbook of Research on Teaching,* Gage, 1963; the *Reviews of Educational Research,* and the *Encyclopedia of Educational Research,* 1969). The ignorance and naïveté displayed in the CAI literature is astounding. Homework is in order.

After the homework the CAI researcher and developer ought to be able to:

1. Work on the application of CAI to critical school problems,
2. Integrate CAI with other media and teacher activities, and
3. Demonstrate CAI's unique capabilities.

The PI (programed instruction) movement went through all the errors and excesses that CAI is now reliving. The failure of PI to find a way into the school curriculum should serve as a warning to CAI enthusiasts.

Review of Several Relevant Papers

Oettinger and Marks (1968) reviewed current research and development on CAI and concluded that the short-range claims will not be realized. This is sure to be so because CAI is being built upon a house of sand: the value of individualized instruction. While nearly everyone pays lip service to this glorious notion that children will learn most and best under an individualized regimen, there is little or no evidence to support the idea. As a matter of fact, there is evidence that group instruction will be preferred in a variety of situations as more stimulating and productive.

Oettinger and Marks also point out that CAI enthusiasts, like their PI predecessors, are wont to set minimal competency goals or objectives. Whatever individualization is afforded is then limited to attainment of these simple objectives. The broader goals of education which are widely regarded as more valuable, even if less well specified, are neglected completely. Thus, there is even the antithesis of the most worthwhile kind of individualization built into CAI. Narrow specification of objectives in simple "behavioral" terms may lead to a denial of individualization in the best sense.

Oettinger and Marks pessimistically draw the following conclusion:

> . . . the observed combination of institutional rigidity with infant technology will preclude really significant progress in the next decade if significant progress is interpreted, in accord with contemporary literature, as widespread and meaningful adoption, integration, and use of technological devices within the schools. In addition, this discussion should suggest the enormous difficulties that will have to be overcome if educational technology is to be introduced in any decade in the twentieth century (p. 708).

They go on to assert that "Contemporary psychology can tell us essentially nothing about the details of individual learning processes." This is an exceedingly pessimistic statement, but one which nevertheless is essentially true since the psychology of learning has mainly been concerned with general aspects of learning which hold true for all learners, not with idiosyncratic aspects of learning. They urge that we acknowledge our ignorance, go about the business of scientific research on individual learning in diverse ways, and desist from our current efforts to apply imagined science to real problems. We cannot disagree.

In a reply to Oettinger and Marks, Ellis (1968) complains that they should not have simply told us what CAI cannot do, they should have, as computer experts, told us what computers can do. Now this is indeed getting the cart before the horse. Having proven that educators and psychologists do not really know what they are doing concerning individualization of instruction, Ellis would have Oettinger and Marks tell us how the computer will do it!

In another reply to Oettinger and Marks, Suppes (1968) argues that there indeed is, or can be, individualization of instruction in CAI (although Oettinger and Marks' argument was essentially that we know of no bases or advantages for so doing at present). Suppes describes three approaches to individualization for his "drill and practice" system:

(1) Individual presentation, evaluation, and repetition of problems,

(2) Individualized levels of difficulty, and

(3) Individualized review activities.

It seems likely that with computer presentation, control, and processing of information on student progress, these limited aspects of individualization might be done more effectively than by PI, live teacher, group instruction, or BOOK.

Finally, Glaser (1968) reacts to Oettinger and Marks with a thoroughly paradoxical statement. First, he agrees that we know little or nothing about individualized instruction. Then he says:

> As a countermeasure to Oettinger's statement, it is necessary to reaffirm that the most pressing need in education today and in the foreseeable tomorrow is the individualization of instruction, generally defined as adapting instruction to individual characteristics and background. Education dedicated to this end can not only maximize individual competence, but provide every individual with a sense of pride and uniqueness, and a feeling of capability to assist as a full-fledged member of society (p. 740).

This thing about which we know little or nothing, individualization of instruction, will nevertheless help every individual become a full-fledged citizen! Glaser goes on to describe a model for individualized instruction, built on faith, intuition, and experience with PI, which *is* undergoing substantial evaluation in his IPI (individually prescribed instruction) project.

Stolurow (1969) admits that CAI is no panacea but suggests that it is a substantial educational innovation. Like Glaser and others in PI, CAI, and CMI (computer managed instruction), Stolurow expresses utter faith in the individualization of instruction. The question is not "should we," but "how"?

Acknowledging that current CAI programs are neither exciting nor effective,

Stolurow places the blame on our meager knowledge of how to teach and our lack of an empirically validated theory of teaching. He urges that we develop such a theory within the setting of CAI. For several reasons this seems inappropriate. First, a theory of instruction developed within CAI would probably be grossly infected with the narrow view of learning currently held by CAI enthusiasts. Second, the poor instructional products which so far have emanated from CAI projects scarcely indicate that CAI enthusiasts know what they are doing. And third, there remains so much need to develop better hardware, systems, and languages than currently exist that these latter three tasks might better be the major preoccupations of CAI.

Stolurow describes the various modes of CAI instruction and then concludes that

> No other instructional system is as versatile with respect to performance, nor as flexible with respect to the degree of individualization it can produce (p. 11).

But shortly thereafter he says

> The true state of affairs is that these modes are in need of a great deal of additional development to provide the requisite sophistication for proper implementation (p. 12).

With the latter statement we agree heartily. To the former we say, BOOK is, at present, the one instructional system, particularly when wedded with teacher, which can serve as an amazingly versatile instructional system.

Stolurow also suggests (p. 13) that research is needed which will relate personal historical information to instructional decisions. This should be extended to include the relating of information about ongoing performance to subsequent decisions in the instructional program. Stolurow further suggests that a CAI programer must commit himself to a theory of teaching as prelude to gathering empirical data concerning individualization of instruction. In light of his earlier pronouncement that we lack validated theories of teaching (p. 3) this is a patently contradictory suggestion. Stolurow finally comes to believe his own theoretical speculations to be truth when he says, "The main advantage of the CAI system is the degree to which it permits individualization of instruction (p. 15)."

Stolurow proceeds finally to speculate about cost factors and to compare the cost of CAI with the cost of live teachers. There was a time when Stolurow deplored such comparisons (1962) when they related to PI. Now, in the setting of CAI with $$$ as the criterion variable, he says that the cost to accomplish equal ends will be about the same in the not-too-far-distant future. Much of the Stolurow paper has an unrealistic theoretical quality which does not augur well for CAI nor for research and development in this field.

Rogers (1968) reviewed current problems in CAI from quite a pessimistic point of view. Among other things the lack of quality course material constitutes one of the most serious CAI problems. There is simply no significant nor even discernible output of evaluated material. Programer-course-developers also seem to be rare. The suggestion that user-teachers develop their own programs is, of course, impractical in light of the time and talent requirements described by several CAI developers.

In one of the more realistic statements to appear in the CAI literature, Karl Zinn

(1968) says, "The benefits unique to computer presentation and control have not yet been demonstrated." He goes on to assert that few people have used capabilities beyond those afforded by the printed page. Zinn feels that the potential of the computer as an information storage and retrieval system may offer more to instruction improvement than the current author-controlled didactic instruction which so often prevails.

Kanner (1968) wisely reminds us that all of the claims, the problems, and the talk of CAI have been heard before (one experiences *déja vu*). The PI movement went through all this–extravagant claims, preoccupation with abstract theory, and inadequate payoff. So did films and TV Kanner pleads for a moratorium on promises of what CAI will do.

Randall and Blaschke (1968) and the same authors for General Learning Corporation (1968) have carried out extensive cost analysis studies of CAI and have developed a systematic model for such analyses. In the first they wisely point out that we do not at present have adequate achievement assessment units which could be used in cost analysis and comparison studies. Thus, primary attention should be devoted to the development of such measurement units and procedures.

In the publication for General Learning Corporation, Randall and Blaschke proceed to analyze various aspects of CAI and other forms of instruction in relation to cost factors. This analysis leads them to conclude that:

(1) CAI will not be used in general educational institutions until costs fall sharply,
(2) CAI facilities will have to be used for more time than the usual school day or week,
(3) CAI programs will have to be prepared for mass distribution,
(4) A single, comprehensive, easy-to-use, programing language must be developed or translation among languages must be simplified, and
(5) The problem of opening the school schedule for individualization of instruction must precede CAI application.

Randall and Blaschke conclude by asserting that the potential of CAI is unknown, the cost of research to develop it further will be inordinately high, there have been too many small CAI projects, cost effectiveness studies are premature, and criteria of learning performance are sorely needed.

Kopstein and Seidel (1968) have done an elaborate analysis of economic factors in CAI. Perhaps the only justification for this analysis, in the light of our primitive knowledge of ways to measure learning, is the authors' otherwise extensive knowledge derived from their large project IMPACT at HumRRO. They acknowledge the hazard of comparing CAI with TAI (traditionally administered instruction) since objective information from research is not available. Thus, they look back to PI research, from which they conclude that PI and TAI were found to be equally effective!

They further assert that it is not fundamentally a question of what PI, CAI, or TAI can produce in the way of learning. Basically our efficiency is determined by our knowledge of principles of human learning, by the way we integrate those principles in an applied instruction situation, and by the way we use various hardware and software as implements for instruction.

From their cost analysis, then, Kopstein and Seidel conclude that in less than 10 years CAI costs will be roughly half the cost of comparable TAI.

Recommendations for CAI Systems, Language, Interface and Program Development

The author reviewed various aspects of CAI hardware, systems, language, and theoretical developments recently (Feldhusen and Szabo, 1969a). From that review, from reviewing the papers cited in the preceding section, and from personal experience with CAI systems, the following recommendations are made:

First, there is a need to standardize and simplify a programing language for CAI. For the present the diversity of languages and the relative complexity of most languages stands in the way of program development and precludes transfer from system to system. There ought to be substantial communication between the potential programer-users of the language and the language developers to assure that the language meets the requirements of program developers.

Second, the system interface needs considerable improvement in many CAI projects. The IBM 1050 terminal or the Teletype terminal, both of which type out messages, are really quite bad ways of communicating with a student. A CRT with a clear image is the minimum essential. The student station should also be improved to the extent of becoming a comfortable and pleasant looking carrel. In many projects at present we see an IBM 1050 standing in open space, in a corner, or against a wall with no surrounding comforts or aesthetic accoutrements. In other methods of individualized instruction (e.g. audio-tutorial), carrels have been developed which are highly efficient and pleasant.

Third, reliability of systems should be high. The frequent breakdown of systems is discouraging to all, including students. Users of CAI begin to doubt that the day of CAI has arrived when they persistently encounter the frustration of breakdowns.

Fourth, there should be *much* communication among systems designers, programers, school administrators, teachers, and students in the design of CAI systems to assure the evolution of functional and useful systems. Furthermore, since innovation and change now proceed at a fairly rapid pace in education, it would be well for CAI system developers to know the current educational scene well. Such knowledge might not only pave the way to effective CAI development for instruction per se, but also for the development of the overall system to service related educational functions such as information storage, scheduling, computation, and accounting.

Finally, there is a need to develop more CAI programs which teach well, which are attractive to students, and which serve a worthwhile educational purpose. For the present there are few effective programs available. Straightforward didactic instruction at the knowledge level should probably be avoided. Instead there should be a substantial effort to design programs in which the student can use large amounts of information, easily retrieved, to solve problems, induce concepts, and discover principles with guidance.

Recommendations for CAI Research

The comments which follow are based on a recent review of CAI research by the

author (Feldhusen and Szabo, 1969b) and on observations in papers reviewed above.

Research on learning with CAI must continually address itself to the criterion problem. One bad way of avoiding the criterion problem is to use available test instruments which only approximate the goals of the program. The CAI programer must specify the intended learning outcomes and develop suitable criterion behavior measures.

If objectives have been stated in Magerian terms (Mager, 1962), then performance and levels of efficiency have been specified. But we have as yet only a limited scientific knowledge of how to develop tests which measure specified behaviors and levels of efficiency of performance. Most of our knowledge of testing is based on the psychometric model which stresses discrimination of individual differences.

Long-range use of terminals in CAI programs should be encouraged to provide experience with students for whom the novelty has worn off. Perhaps the place or time to begin CAI research is with students who are well acclimated to CAI.

CAI researchers should feel free to work within or without the constraints of instructional theory. For some, theory development serves the heuristic purpose of alerting the researcher to all relevant aspects and of providing integration. But adherence to a single theory also blinds the researcher to alternative views. Thus, some people will thrive by being eclectic and exploratory.

For the present a theory of CAI to guide CAI research is downright silly. The essence of CAI is hardware! And hardware deserves no theory. A theory of instruction transcends CAI. CAI is one element, one way of implementing some part of a theory. Of course, it may well be true that certain theories of instruction (for example, Skinner for a conditioning theory or Ausubel for a cognitive structure theory) would serve particularly well as models for CAI research.

CAI research should be well designed, not an after-the-fact piecemeal business. Some aspects of research and evaluation are involved in the development of CAI programs (Scriven's 1967 model for curriculum development illustrates this idea very well) while others appear later. For the present much attention should be devoted to research-evaluation in the development and field trials of CAI programs (Markle, 1967). This kind of research should be a planned part of the overall evaluation of the effectiveness of programs when they are completed; the research should seek to determine the appropriateness of all or segments of the program for various student audiences with differing characteristics.

Applied research on CAI should focus on known principles of learning and on specifically related CAI capabilities. Quite a bit of research on learning suggests that specific informational feedback to the learner about the adequacy of his knowledge or performance increases the amount learned and is well liked by the student. A wide variety of tests of this proposition can be devised in the CAI setting to verify its application there. In PI it was found that the report of correct answers often had little effect in facilitating learning because initial performance was so highly prompted that there was little possibility of error or need for correction.

Gagné (1963) suggested that principles of learning developed or derived in one or several settings must still be verified anew in new applications. This is so because the new

situation may involve elements which are different from previous settings and which change the expected effects. It is also necessary because a complex instructional package involves a number of principles which may interact in such a way that the effect of any one will not be as predicted.

CAI should also be used as the setting or vehicle for new basic research on learning because of the unique capacity of CAI for controlled stimulus presentation, interaction with the learner, processing of responses, and storage and processing of performance data. CAI should be especially useful in research on verbal learning. Carroll (1968) discussed the need for and recent work in this area. The positive results of such research should be useful in applied CAI research and eventual instructional application.

A substantial amount of research should be done on students' affective reactions to CAI. Mager's new book on the teaching of attitudes (1968) emphasizes the need to attend to learning outcomes in this area. However, such research should be done only with students who have been on CAI long enough to overcome novelty effects and who are being instructed at terminals with well designed interface and with *good* programs.

Research on the use of CAI as a data bank for instruction is promising because it capitalizes upon a unique capability of the computer. Substantial efforts should be made to develop and carry out research on this kind of application. As yet little is known about the use of the computer as an information bank in instruction, but a promising beginning has been described (Ciaburri, 1969).

Research on the use of the computer as a control or director mechanism should be explored. For example, the role of the computer in Guetzkow and Jensen's war games (1966) or Wing's economics games (1966) could be extended to comparable activities in the classroom where the efforts of numerous students could be directed by the computer, their performances could be processed, and data could be accumulated and processed concerning individual gains in learning. The role of the computer as director of a complex variety of instructional activities should also be explored. The computer can be used to direct some on-line didactic and inductive instruction, secure and process performance data, and direct the student to other learning resources such as the library or a laboratory.

The role of the computer as diagnoser and prescriber is already being explored in the IPI project (Lindvall and Bolvin, 1967) and its role as processor of student performance data is being investigated in the SIRA project (Easley, 1966). Such uses of the computer should be explored much more for they relate to the teacher and to the use of other media of instruction. Two of the greatest strains of teaching at present are the tasks of diagnosing student achievement and prescribing suitable remedial instruction or the next appropriate level of instructional material.

Research is particularly needed on the use of CAI to teach creative thinking, logical thinking, and problem solving. These more complex cognitive functions place greater demands upon the tutorial functions and on the data bank than the more traditional didactic instruction. Thus, the computer may come to have a unique contribution not available from any other source because of several of its superhuman qualities.

Individual learning styles and adaptations can probably be studied effectively in CAI and should be investigated as an extension of concern with the individualization of

instruction. Again the unique power of the computer to gather, store, and process information about individual students and their choices, performances, and routes through instructional material should provide valuable insights concerning idiosyncratic aspects of learning.

Research on the interaction of individual differences (IDs) with methods of instruction has produced very few significant results. This may be due to poor selection or bad measurement of the ID variables, weak methods, and/or failure to secure appropriate ID assessments of ongoing performance or achievement. Continued and new efforts should be made in this area because it comes so close to the heart of the CAI claim to individualization of instruction.

Subject matter or curriculum specialists will be interested in exploring the role of CAI in teaching various parts of their curricula. Where does CAI work well and where are other media or techniques more appropriate? Closely related are questions concerning how to use CAI as an adjunct in instruction, not as the major vehicle.

Problems of student saturation or tolerance for PI, CAI, or any individualized instruction should be researched thoroughly. For the present we merely guess that on the average students can only stand a limited amount, but some students probably could stand to do all their learning on CAI, while others can stand none. Alternatively the question may be, "How do we make CAI more palatable or interesting?" As yet, nothing quite matches learning in groups with a live teacher.

Finally, CAI research should be well designed. The guidelines of the joint committee of AERA-APA-DAVI (DAVI, 1966) provide a model for evaluative research as do Scriven's model (1967) and Markle's model as set forth in a recent NSEE Yearbook (1967). Applied and basic research of the types described above should employ more robust models of the experimental type described by Campbell and Stanley (1963). Much of the research reviewed by Feldhusen and Szabo (1969b) was of the limited experimental-control group design with small N, poor criterion tests, and brief treatments. Guidelines for effective research are now available from a number of sources and should be employed in new CAI research.

Concluding Statement

Before substantial amounts of new CAI research are undertaken, some major systems problems should be solved. First, an inexpensive CRT should be perfected to replace the typed message. Second, the student interface should be developed as an efficient and pleasant carrel which affords access to several media. Third, time sharing service and terminals should be abundantly available to avoid artificial constraints on instruction. Fourth, one set of programing languages should be developed for several modes of instruction–such as didactic, inquiry, and computation–and for the author mode. Fifth, some lengthy courses (3-6 credits) should be developed to serve as vehicles of research and as models of CAI potential.

With suitable equipment, systems, and instructional software, CAI research can come on hard and hopefully can begin to produce significant results.

Having learned that CAI has arrived, the pessimist appropriately asks, "Who knows if CAI has anything worthwhile to teach?" In truth, there is at present little that is worth teaching in the CAI library. Thus, it seems that it would be profitable to direct much attention in CAI to research and development on course construction.

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Zinn, Karl L., "Instructional Uses of Interactive Computer Systems," DATAMATION, September 1968, 22-27.

This discussion of the potentials and current problems of the instructional applications of computers attempts to persuade readers to invest more personnel and research dollars to make the systems and teaching strategies more usable.

A Brief History

In 1958 three demonstration projects were begun. By 1961, when a conference was sponsored by Systems Development Corporation and the Office of Naval Research, five major projects were underway and eleven different curriculum packages were being prepared, although more than half of these were short demonstration units. The number of projects had doubled by 1963 and doubled again by 1965. Three major conferences were held in 1965 to discuss the problems and potentials of this young technology. At recent meetings of IEEE and ACM and at the Fall and Spring Joint Computer Conferences, special sessions on Computers in Education have been offered.

Another indication of the attention being given this new technology is the number of manufacturers and publishers who are entering the field. Also, sizeable field studies have been initiated in the public schools in Philadelphia, New York City, Boston, Waterford, Mich., and in the schools working with the Stanford University project. The use of interaction computer systems to teach computer programing and mathematics is already widespread.

Status of the New Technology

Interactive instruction has been implemented on a variety of machines from a small, one-student system to larger systems teaching up to 200 students. Up to now it has been difficult to find 200 students capable of using the same or a similar applications program and whose administrators want to pay the price. Other projects have imbedded instructional applications among other software packages available on a general purpose conversational system.

Programing languages and systems show even more diversity than that seen in hardware. The reason for this diversity is that at least five kinds of users (instructors, authors, instructional researchers, administrators and computer programers) have distinguishable requirements. The Inter-University Communications Council (Educom) has a working group on programing languages to study problems and needs in this area.

Costs reported by manufacturers or research projects range from $2 to $15 per hour. One project claims to be able to achieve a figure of 20c per student-hour. Useful papers on CAI economics have been published by Kopstein & Seidel and Randall & Blaschke [an abstract of each is presented later in this collection of abstracts].

Instructional materials have been written in many subject areas and for many age levels. Some of these make little use of the computer and would be as effective and less expensive in another mode, such as a book or film cartridge.

Factors Affecting the Value of CAI

Five ways of using the machine are likely to be important when the typical self-study material is adapted for computer presentation:

(1) The machine evaluates and corrects the student according to the author's criterion
(2) More complex control over the presentation of material is exercised by the author
(3) The computer is used to execute student programs
(4) Detailed records of student performance are kept
(5) The author can modify his material with relative ease.

Computers, to do these things, will require much greater specification in the subject matter than exists at present.

Examples of Current Uses

Applications appear to vary along dimensions of program or author control of the student. At one extreme the student can do only what the program allows; at the other extreme complete control is given to the student. In between are applications which specify how the computer responds but give some freedom to the student. In addition, there are applications which involve instructors and researchers.

Drill, Tutorial and Dialogue

These three categories are most often labeled "CAI." These applications allow very little student control. Because of the relative ease of assigning large numbers of students the same material and serving them from a relatively small machine, many student-terminal hours have been logged in drill type programs. This approach has not, as yet, proved economical. The Suppes and Atkinson work in mathematics and language skills for the elementary school is best known. Tutorial applications typically involve adaptations of lecture or textbook material at the college level. The benefits have not yet been demonstrated, although the authors are compelled to develop their material more carefully. Some programs of a tutorial variety are designed to converse with the student, giving the impression, for example, that the computer is "discussing" a problem in medical diagnosis.

Simulation and Gaming

Applications in this area are marked by the fact that details of the conversation between the student and the

machine do not have to be pre-specified, and this gives greater control to the student. The programs typically exercise the student's decision-making skills by closely or abstractly modeling or simulating a business or military problem. Games represent even more abstract training settings. Applications of both gaming and simulation are found in such areas as college chemistry and high school career planning.

Aids for Information Handling

Demonstration projects such as those developed by Ralph Grubb or Douglas Englebart have the potential of allowing a student to search through, and organize, information from large text files.

The computational mode of the computer is often overlooked by CAI planners. Projects such as the statistics teaching effort at SDC have students write and execute progressively more complex computational routines at an interactive terminal. The Culler-Fried graphic display system has been similarly used by science and mathematics students.

Aids for Instructional Management

This application involves using the computer to aid the school administration and instructors in handling the clerical burden of the school.

Trends and New Directions

The current trend appears to be away from the programing of sequences to be delivered by the computer under strict control of the author's rules. More control is being given the student. Research on natural language processing, information structures, and computer aids to human intellect will produce better tools for authors of CAI material. The production of materials will be automated. Finally, there will be more cooperative efforts on material development. Ideally, resources of entire regions will be available to enrich and individualize the education of every student.

Rogers, James L., "Current Problems in CAI," DATAMATION, September 1968, 28-33.

This article considers the progress in CAI to date, identifies some of the difficulties that have been encountered, and suggests changes needed if matters are to improve.

Ways Computers Assist Instruction

The discussion is limited to those ways in which the computer output produces an effect on the instructional interaction. The six different categories are: computational aid, simulation, lesson material storage and retrieval, lesson presentation, testing, and interactive instruction. If CAI is to evolve as a useful tool, three problem areas need to be resolved:

1. Gaps in the Instructional Process

The most widely known application of computers to instruction is the drill-and-review material developed at Stanford University. Typically each student leaves his class to spend 5-10 minutes at a Teletype terminal working on 20 drill-and-review questions. His performance is summarized for the teacher.

The most important problem raised by this approach is the lack of direct interaction between the system and the classroom; it is left to the teacher to interpret and apply the results of the computer-administered test. Yet Suppes remarks that the teachers cannot possibly digest all the data a computer could generate on the student's performance. How can they then use this to advantage in the classroom? It is the kind of problem Skinner notes when he describes efforts which concentrate on " . . . measuring the results of teaching while neglecting teaching itself."

2. Limitations Imposed by Systems

There are few generalizations useful in answering the question, "What limitations does this system impose upon the material I need to present, and upon the responses I must elicit?" An analysis of system input-output capabilities and the stimuli-responses needed in instruction to prevent a mismatch is required. We might wish text, audio, and/or graphical material to be presented. This author does not know of any operating system that is capable of presenting material in all these modes. The kinds of responses desired might include outlining the temperate zone on a map, defining a concept, or summarizing the speaker's remarks orally. Each kind of response poses a different hardware or software problem. The usual solution is to allow the tail to wag the dog. To the extent that we allow our inability to resolve problems of handling the learner's response to modify the required response, we degrade the quality of the instruction.

Several approaches to solving the problem have been tried, including use of "off-line" supplementary material, modification of the system (e.g., typewriters with Cyrillic keyboards to teach Russian), modification of the teaching objectives, or concluding that CAI is inappropriate. None of these approaches is entirely satisfactory.

3. Production of CAI Teaching Materials

Partly because of the lack of qualified personnel, there is a shortage of quality CAI course material. The discouraging example of the unimaginative use of educational television should stand as a warning that the availability of hardware is not enough to result in improvement in education. The computer can be an effective educational tool only if care is taken in designing the course material. It has been variously suggested that manufacturers, publishers or teachers design the material. With the latter group two problems emerge: (1) The time required is more than teachers can spend; approximately 100 hours of development and editing time is required for each hour of student material. (2) Few people possess the diverse skills required to prepare self-instructional material. Usually a team of subject matter experts, behavior analysts, programers and editors is needed. Manufacturers have helped little. The current CAI manuals assume that all the educational questions have been solved and also seem to assume that the user has a background in electronic data processing concepts and procedures. The shortage of people with the necessary skills and the lack of CAI materials have forced teachers into preparing their own material.

Some major textbook publishers, in alliance with RCA, have begun to develop instructional materials. This has great potential for simplifying implementation of CAI. The publisher, however, runs the risk of investing in material which will become obsolete before he regains his costs.

Suggestions for Future Developments

(1) Funds should be spent to determine how the teacher can use the summarized test data. (2) More work needs to be done on natural language processing. (3) Projects should be devoted to making the computer do what it alone can do. (4) A common CAI language needs to be specified. (5) More-reliable, less-expensive components need to be developed.

Kanner, Joseph H., "CAI–The New Demonology," DATAMATION, September 1968, 38-40.

It may be strategic to review the recent past as a prelude to judging the soundness and validity of the present enthusiasm for computer-assisted instruction, which is supposed to succeed where programed learning, teaching machines, television, and motion pictures failed.

Motion pictures have a long history of research. Training films were supposed to standardize instruction at a high level of effectiveness and be an excellent medium for conducting research into the human learning process. One of the major surprises in all this research was the triviality of much that was discovered. Most of the studies yielded indecisive results or findings which could not be generalized. One repeated finding was that showing a film more than once was probably the most effective way of promoting learning. A mountain of research produced mouse-like results.

The advent of television was heralded as the new answer for it had all the advantages, but not the disadvantages, of film. Yet many educators are reluctant to use it, and it is most often used with the same production techniques used for motion pictures. Promises of new insights into human learning have not materialized.

The rise of programed instruction was widely heralded as offering many of the same promises. In 1959 the writer commented that adequate evidence on the advantages of this technique did not exist, and that no evidence existed to demonstrate that the cost of programed instruction was justified. What would be the result if the time spent in planning and programing for automated devices were spent with conventional teaching methods? In the ten years since then, most of the promises have proved empty or exaggerated. Most research pitted a painstakingly developed programed version against an unimproved conventional version without yielding demonstrable benefits to the student.

Now advocates of computer-assisted instruction are repeating the history of their predecessors. A voluminous literature has already appeared. CAI research needs standards for criteria used in measuring its effectiveness, as well as some effort to develop general software systems.

An evaluation of the effectiveness of CAI and its place in future education must be based on the following considerations:

We have no general laws or hypotheses of human learning comparable to those in the fields of physics or chemistry. Computer-assisted instruction possesses no superiority over the other approaches in its knowledge of human learning.

Standards of continuance or rejection of computer-assisted instruction research, based on such factors as student learning and costs, should be established.

A moratorium on promises not yet supported by facts should be declared, and criteria describing limitations of research efforts should be established.

Stolurow, Lawrence M., "Computer Assisted Instruction," in THE SCHOOLS AND THE CHALLENGE OF INNOVATION, Committee for Economic Development, 477 Madison Ave., New York, 1969.

An analysis of CAI as a concept clearly suggests that while it is not a panacea it does have the potential for making at least a one-order-of-magnitude change in the educational process. Methods of communicating information in general, and books in particular, do not operate on an individualized basis. None is designed to modify the message to fit the person addressed. If we are to individualize with the new technology we have three alternatives: continue with the present practice of reworking materials to fit special groups, move in a new direction and develop CAI, or try to combine the best of both.

CAI has not developed to a production state where it is easily combined with other approaches. Since most current CAI efforts are prototypes of a temporary nature, projections based on today's systems would have no more accuracy than projections of the design of the SST based on the Wright brothers' first plane. Projection is not our real concern anyway. More importantly, we need to decide whether we believe in CAI. CAI makes our ignorance about teaching obvious. It reveals our present, most pressing problem: the lack of an empirically validated theory of teaching. But we need not wait to start—we only need to hold off widespread implementation. The system development process for CAI needs to be evolutionary and cumulative. At the very least, CAI systems have demonstrated that they can teach and aid the teacher.

Purposes of CAI

It seems useful to distinguish between ultimate and immediate purposes. For the ultimate purpose, we must keep in mind two unique characteristics of CAI, both of which are aspects of the computer: a large memory and a flexible logic. No other teaching aid possesses them.

The immediate purpose comes from one of the sounder generalizations of behavioral science. Individuals learn at different rates. The main immediate purpose for CAI should be to provide education with a means by which instruction can be individualized. Unlike programed instruction and other free standing display systems, CAI is a response-dependent, cybernetic instructional system. At the least it can do programed instruction; at the most it can make very complex instructional decisions. This can best be seen by examining the five "modes" of CAI use:

1. Problem Solving. The student uses two-way communication with a computer to solve his problems. For this he has to learn the appropriate language for conversing with the system.

2. Drill and Practice. The student communicates with the computer to answer problems the machine presents. This mode involves the instructional staff in the preparation of appropriate materials.

3. Inquiry. The student asks questions for which the machine has stored answers. The instructional staff needs to develop the filing and searching procedures used.

4. Gaming and Simulation. The instructional staff formulates a model of some real or idealized complex situation. The student must learn to work with and interpret the involved relationships among the variables that represent the situation.

5. Tutorial Instruction. The system presents information, asks questions, and interprets the student's answers. The instructional staff is responsible for formalizing the logic of instruction and entering it into the system. The instructor also has to formalize his philosophy of teaching and the specific strategies he wants to use at each step of instruction. Three types of teaching rules can be used: rules for controlling the conditions used to present information, rules for response processing, and rules for allocating methods of presentation. On the basis of the complexity of the contingencies involved, higher-order rules involve the "professor" function of CAI while lower-order components have been identified as the "teacher" function. In the tutorial mode it is possible to utilize a CAI system at either level, although the main concern of current research is at the "teacher" level. The student needs to know very little of how the CAI system works, while the instructor or his staff must know a great deal about the system in order to develop the programs.

6. Author Mode. In this mode the CAI system is used to support the generation of material for student use in the drill and practice or tutorial mode. This mode can be implemented in a more more sophisticated way than it has been.

No other instructional system provides the flexibility or versatility that CAI can. In addition, CAI allows the collection and immediate use of detailed records of student performance.

No CAI system uses all of these modes in presenting a course. Further, no one mode has been used enough to establish an optimal instructional condition for its use. Since they are all possible with live teachers as well, it is important to study them in order to improve our knowledge of the teaching processes. The optimum use of each mode will be determined by the student's entry characteristics with respect to ability, aptitude and personality, and by the influence of these characteristics on the nature of the reinforcement and on the sequence used during instruction.

Additional important purposes of CAI include finding the way in which the personal history of the student is most effectively used to optimize his instruction, and the translating of theories of teaching into practice.

Advantages of CAI

One of the advantages of CAI is the dynamic interchange it provides between the student and the instructional system. Some systems have the ability to interpret constructed responses so as to match the student's effort with the instructor's intentions. CAI can conceal or control the amount of information displayed to the student. It can also, with elaborate consoles such as those for the IBM 1500 system, coordinate various audiovisual displays for the student, permitting their use in selective and imaginative ways. All these options are equally available to the author in developing the course material.

In summary, the main immediate advantage of individualizing instruction derives from the capacity for doing research on teaching under controlled conditions, collecting data on the effectiveness of the material and methods, and developing ways of assisting in the preparation of new instructional materials.

Applications of CAI

CAI systems need to be programed to be used and these programs are, in effect, models of instruction. Mathematical models and optimization models are available and provide a basis for evaluating the effectiveness of instructional rules.

1. Development of CAI Models

Models have differing purposes. Some models are built to describe, while others predict performance without description. Some models are molar (predicting general outcomes), while others are molecular (describing what happens to the individual). Models differ in the number of outcomes they predict. The more useful models, obviously, are those that predict more outcomes. A model that is effective in predicting learning outcomes may not describe the procedures a teacher uses to accomplish the same thing, but it could be used as a prototype for useful teaching procedures. Individual elements of a successful model are not indispensable, and so the correspondence between a model for learning and a model for teaching need not be one-to-one. Even though there is no unique solution to finding an effective model, it is useful to do two things: make the set of relationships in teaching explicit and correct mistakes in teaching assumptions. By articulating a set of factors in a model, clarification and continuity can be increased.

2. Curriculum Planning for CAI

CAI systems can be applied in several useful ways in planning a curriculum: to retrieve information, to identify objectives and implement them at desired points, and to establish a reciprocal interactive relationship between the curriculum and the student.

3. Man-Machine Relations

The interface—the equipment which relates the system to the learner—has two main aspects: display and response. The main concern in designing the interface is to relate the system to the learner, although the same interface may be used by the author. In the design of a system one has to distinguish between the Central Processing Unit (CPU) and the consoles. For a particular CPU the consoles may be as simple as a teletypewriter or as complex as an IBM 1500 system terminal with cathode ray tube, keyboard, light-pen, image projector, and audio system.

Assessment and Evaluation

CAI may be used to collect information not now available about student performance in complex problem situations. Another purpose is to evaluate performance before, during, and after instruction. In evaluating student performance two different kinds of objectives can be distinguished: psychological objectives such as retention or transfer, and content objectives. Evaluation of learning content objectives would be done during instruction, while retention and transfer objectives would be evaluated after instruction.

Traditional evaluation is usually based on "obvious" methods such as tests. CAI makes it possible to use "embedded" evaluation. It would be possible to present items relating to a previous course in evaluating the student's learning in another course. This can be done to determine transfer of training, which is a difficult process to measure in other instructional systems.

An evaluation of the adaptability of the system itself is also possible by calculating the degree to which it can generate a variety of paths through a set of materials. This "teaching system index" would assess the power of a system in adapting to individual response histories.

Economics

The growth-rate of the educational market is already more than twice that of the gross national product. The national government is currently the major contributor to developments in education. Industry is also contributing at a growing rate.

The Most Visable Companies

The Radio Corporation of America (RCA) has recently become interested in the use of computers in education through its Instructional Systems division. Up to 200 student terminals can be attached to its Spectra 70/45, and this system would cost about $20,000 per month to run.

Philco-Ford, through its Education Development Center, entered the field with funds from the Philadelphia School District. The system also services Dover, Delaware. An Automated System for Education was developed with a $1.6 million federal grant. The system uses as CRT displays converted television sets, making it possible to display videotapes or broadcasts.

IBM has probably made the largest investment of its own funds in CAI. Various development projects have been conducted within IBM, e.g., the Thomas J. Watson facility in Yorktown, N.Y. There have been several systems—1401, 1410, 1440, 1620, 1710, and 1500. Most of these are oriented to the IBM 1050 terminal and have software that permits both author and student modes of application.

Useful cost figures are difficult to present. Terminals cost approximately $250 per month. Line costs and interface costs represent additional expenditures. To these costs

must be added CPU rental. When all of these costs are included and a high degree of use assumed, a figure of about $7.42 per student hour per terminal is reached for the IBM 1400 system.

More recently, IBM designed a system especially for CAI, the IBM 1500. This system utilizes "rich" terminals which incorporate an image projector, CRT, full keyboard, and an audio recording and playback system. A single CPU can handle 32 terminals. With 300 hours of use per terminal per month the cost per terminal hour would be $1.95, illustrating the reduction in systems costs made possible in just a few years.

Overall Costs of CAI

The cost of the system is not the total cost. To it must be added the cost of developing educational programs which could range from $120 to $480 for one hour of instruction at the terminal. Other costs are involved but hard to estimate.

The average expenditure per student in the public schools last year was $564, or about 56¢ per student hour. It might be noted that the average cost of keeping a delinquent in a detention home is 4.5 times the cost of keeping him in school, and thus is more expensive than the $1.95 per hour a CAI system costs. In yet another context, the medical school, the 1500 system would cost as much, and provide the same number of instructional hours, as 12 professors at $20,000 per year.

These mathematical exercises illustrate that the present cost of CAI is close enough to that of current educational alternatives to warrant consideration on economic grounds, especially since the cost of CAI is predicated on limited availability. The cost curve for CAI is decreasing while the cost of traditional classroom teachers is increasing.

The problem today is whether we want to take CAI seriously enough to commit resources for the research and development needed to reduce its cost and improve its capability so that it is economically competitive in the near future.

Oettinger, Anthony and Sema Marks, "Educational Technology: New Myths and Old Realities," HARVARD EDUCATIONAL REVIEW, Fall 1968, 697-755.

Industry asserts, in advertisements, and USOE officials claim that technology will revolutionize education. Our conclusions are less enthusiastic. For example, the claim that technology will usher in "individualized instruction" demands a closer examination.

Individualized Instruction

Many psychologists agree that individuals differ in learning capacity. But what does it mean to "individualize" instruction for these individual differences? A case can be made that it means personalizing a mass-produced object. This would be superficial. A loftier definition implies "giving full scope to idiosyncracies." To current practitioners, the meaning lies in between, but precisely where remains unspecified. That "individualization" is a panacea is usually claimed. For example, while officials of the IPI (Individually Prescribed Instruction) Project at a Boston school only claim concern with individual rates of progress, others misrepresent this part as the whole of possible individualizations, claiming such things as "Youngsters of all ability levels will learn more. And they would enjoy school far more, thus reducing discipline problems."

When educators speak of exactly what they intend in terms of behavioral objectives, the object is clearly not cultivation of idiosyncracy but rather "mass production to narrow specifications with rigid quality control." Further, if students are allowed to proceed at their own rates the spread between the fastest and slowest becomes quite large. (One of the appeals of "lockstep" is that it minimizes this and reduces the teacher's problems in processing information.) Even when computers are used to schedule students for continuous progress, the matching of students to teachers and classrooms is done once a term, not continuously. Thus the practices are some distance from truly individualized instruction.

Systems and Schools

Computers are not now the great individualizers of instruction and may never even be useful in schools unless these schools are drastically reorganized and appropriately funded to absorb reform. Every change in a school reverberates throughout the community. Even minor changes tend to meet with resistance in the community and with teacher intransigence. The educational system, tied as it is to many apron strings, is far more complex than anything we have hitherto tackled.

A system which is amenable to change is characterized by relative independence from other systems, well developed research and design tools, and goals which are well known and specifiable. School systems have none of these characteristics. There are 27,000 local autonomous school districts and boards. Even when the board decides to innovate, implementation is left in the hands of the teachers. Teachers are not accustomed to working with anything less reliable than a blackboard, a criterion new technologies cannot meet.

Our general conclusion is that the observed combination of institutional rigidity with an infant technology will preclude really significant progress in the next decade, if significant progress is interpreted as widespread and meaningful adoption, integration, and use of technological devices within the schools.

Two Examples

1. The Language Laboratory

The language laboratory operating in the Watertown, Mass., Public Schools has not achieved its goal of individualization of instruction and the equipment is too easily damaged. Although each student hears the spoken language and responds to it individually, the teacher is still very limited in the amount of time she can spend listening to each student. Further, for students who are used to sounds blaring in their ears, time in the language booth is reportedly good for "day dreaming."

2. Stanford-Brentwood

Although described as an integral part of the school, the Brentwood CAI laboratory is in a separate building staffed by its own people. Students are taken into this building and kept for a guaranteed half hour of instruction. The experiment is wisely limited to what Suppes calls "drill and practice," but still major problems of integration and training arise even with this simple computer use. The whole course, either in reading or mathematics, cannot be available at one time. Scheduling problems for students on this, or a larger system, become great. The system is costly, from $1.40 to $7.00 per student-hour, which looms quite large when one realizes that a district like Watertown spends $4.00 per year on books for each student. The bulk of Watertown's school budget (80 per cent) goes for salaries, and neither the Watertown language laboratory nor the Brentwood project has resulted in any manpower reduction.

The Longer Range

What holds back progress in education is not that the scientific method has failed us, but that it has so far revealed very little of systematic value in attaining the goals of education. Attempting to design an educational system with our contemporary scientific apparatus is rather like giving Lucretius an imperial grant to make the bomb, starting with his atomic theory. Our ignorance need hold no special terror, but it does argue against any form of strong coordinative planning and prescription on substantive

matters. We should, in short, plan for the encouragement of diversity, at least in technique. We should have a chance to "fiddle around" with both goals and techniques, and we should give people enough freedom and options so they need not feel like unwilling victims of any particular experiment.

Discussion of "Educational Technology: New Myths and Old Realities"

Maurice Belanger, Harvard University

I am not convinced that the new technology can be dismissed as just another round of innocuous technological innovation (in the short run) and I would like to raise four points about the long-run comments made by Oettinger.

1. As usually used, "technology" in education implies hardware. It has a more general meaning implying "technique" and there is the possibility that educational problems and issues will be distorted to those susceptible to the application of technique–validly or not.

2. Oettinger tends to place computers in the category of gadgets. Instead, should we not be discussing "programs" as ordered procedures generated by, and reflecting, human intelligence?

3. Does Oettinger's analysis pertain if the pupil-computer relationship cannot be compared to the pupil-"thing" relationship of the past?

4. "Our methods are mechanical and superficial. . . . So long as people like showy mechanism in our schools, so long they will have it." [The American Education Monthly, 1873]

Allan B. Ellis, Harvard University

Oettinger, who has a very important point to make, shows a certain lack of care in making that point by his use of advertising and sales pitches as definitive statements about educational technology. Further, while he points out that letting machines dictate practice is foolish, Oettinger talks about technology as if it existed apart from its educational application.

For all his warnings about institutional rigidity and infant technology, Oettinger seems to take it for granted that, eventually, progress will be made. Demonstration of this possibility should be the first order of business.

As a computer scientist, Oettinger should have addressed himself to the question "What kinds of machines can computers become?" rather than the more usual question "What do computers do?" He did not miss this question out of ignorance for as early as 1952 he had already written of the significant role computers can play in helping people understand and deal with their own theories in their own disciplines. What we in education need from Oettinger is a sense of how technology can help us determine what needs to be done.

Patrick Suppes, Stanford University

I shall concentrate on one of the two critical concerns considered by Oettinger–the problem of individualization of instruction. I support much of Oettinger's criticism that individualization is a vague concept in education and I agree that only to a limited extent can we expect teachers to carry the responsibilities of individualized instruction.

To bring a sense of concreteness to the discussion, I would like to review three programs now in operation at Stanford:

1. Drill and practice in elementary mathematics has been run on a medium-size computer (PDP-1) for more than 2,000 students in California, Kentucky, Mississippi and Iowa during 1967-1968. The central purpose is to provide daily practice supplementary to the teacher's regular classroom instruction. Individualization takes place in three ways: the pace of problem presentation and the evaluation of the student's response, the organization of the problems in terms of difficulty, and the selection of individualized review. Even the most energetic teacher would have a hard time matching the first aspect–"on-line" responsiveness to individual answers. In terms of Oettinger's essay, this is the drill and practice program which he confuses with the tutorial program at Brentwood.

2. The Brentwood tutorial program is more radical. The three kinds of individualization described above are part of the Brentwood system. In addition, the students can determine their own progress through the curriculum, and all students do not eventually progress through the same curriculum material. While it is certainly true that the Brentwood system is too expensive for widespread use, it represents

an attempt to develop an adequate tutorial system.

3. Computer-based instruction in elementary Russian represents a counterexample to the claim that the number of teachers is not reduced by CAI. In this course the regular classroom teacher has been totally eliminated. The students continue to do homework and go to the language laboratory, but regular classroom instruction has been eliminated. By teaching Russian at a computer console the situation is individualized in a most important sense. Every single response is required from the student sitting at the console. No question to, or responses from, other students enter the picture.

Even though our work at Stanford is in its earliest stages, we feel that it shows how computers will be able to improve education by individualizing it in the several important interpretations of that phrase described above.

Warren G. Bennis, State University of New York at Buffalo

After three readings of Oettinger's article, I am left with the inescapable conclusion that there is less here than meets the eye. He begins with the revolutionary assertion that advertisers and commercial vendors occasionally overstate the case for educational innovations, and follows this with another outrageously bland assertion that school systems are rigid places.

But there is a growing literature on educational innovation which indicates that, while the rate does not satisfy me, changes are taking place. We know much more about the forces which block and facilitate change than Oettinger seems to recognize. New theories of "changing" are being developed so that planned changes can be directed and implemented. While most educational social systems are more impervious to innovation than other institutions, the growing literature on the subject deserves Oettinger's attention.

Robert Glaser, University of Pittsburgh

I have two overall reactions to Oettinger's paper. It does not respond to deep investigations but only to material written to persuade, and Oettinger does not concede what he must know: that behavioral science is advancing like other sciences, from application to theory as well as from theory to application.

To Oettinger's statement that " . . . we remain at quite some distance from implementing truly individualized instruction in the classroom," I can best reply by reaffirming some old values and stating a general model for implementation. The most pressing need in education is to adapt instruction to individual characteristics and background–to individualize instruction. To recognize this and the goals related to it is a first step, but as a scientist, I am primarily concerned with the operational mechanisms for accomplishing this. Different definitions for individualization can be proffered, but incumbent on any definition is the necessity to point to operational and practical implications. My concern is with subject-matter learning and personal-social learning, which can be developed in the course of subject-matter learning. My definition of individualization is "the use of information about individual behavior to prescribe appropriate educational environments." For implementing and investigating individualized instruction, I have developed the following model:

1. The outcomes of learning are specified in terms of observable competence and the conditions under which it is to be exercised. A major failing of education has been lack of behavioral objectives. Objectives, when too generalized, lead us to settle for what is easily expressed and measured.

2. Detailed diagnosis is made of the initial state in which the learner comes to an instructional situation. This should include measures which are relevant to the next instructional step to be taken, in contrast to the usual tests used to predict long-term performance.

3. The immediate instructional step consists of educational alternatives adaptive to the performance profiles determined in the student population. Putting the student in direct contact with the subject matter and letting him obtain feedback is important here.

4. As the student proceeds, his performance is monitored and assessed at shorter or longer intervals, as appropriate. Rate of learning, with which we are concerned in the IPI project, can be a very important, informative index on which to base individualization.

5. Because assessment, instruction, and performance are interlinked, the learning outcomes to be optimized are critical. It is important to study, as I have been doing, the kind of information needed to make effective instructional decisions by the teacher and/or the student. I suspect that individualization will be introduced to the schools first by some non-automated system, such as IPI, to which computer-management would be added.

6. The system has inherent in its design the capability for accumulating information on the basis of which it can improve its operation and come closer to its goals.

Exhortations to change are less effective than the providing of materials and equipment (including computers) which are the vehicles for change. Tangible equipment becomes rapidly disseminated, not only in education, but also in medicine and engineering. One answer to Oettinger's concern that people and equipment are not up to changing education is to introduce the concepts of development, design, and field testing, generally associated with these other fields. The application of behavioral science to practical human affairs is going on, perhaps faster than Oettinger thinks.

The examples Oettinger uses are loaded examples. The language laboratory was put on the market before modern

notions of programed instruction became popular. Oettinger's comments on the Brentwood project are premature, for it is an experimental system intended to be improved and re-designed.

For the longer range, Oettinger fails to acknowledge the two-way interaction between science and application. I would suggest that intense application of their discipline by behavioral scientists to educational problems would be more helpful than the decrying of the lack of basic knowledge.

James W. Becker, Research for Better Schools

Whether technology will bring glowing changes to the schools of America is almost irrelevant when weighed against the present reality. For example, in Newark, New Jersey, the school system is in "an advanced state of decay," with the prospect that one half of the students will be functionally illiterate when they graduate from high school. Thirty-five of the 50 elementary schools are operating at from 101 to 151 per cent of capacity. Needless to say, Newark is in serious danger of losing a majority of its teachers.

Anyone can be pessimistic about our schools, but the point missed is that society gets what it wants, and what it has wanted for years is schools that are just barely good enough. The only possible conclusion is that the cities' public schools are no better than what the people who control the money have wanted them to be. Educators do not make basic educational policy. This is of central importance because it helps distinguish among several kinds of possible improvements. If there is a note of hope today, it is that financial deficiencies are beginning to yield to the forces of desperation.

I feel somewhat responsible for correcting Oettinger's presentation of Individually Prescribed Instruction (IPI). Rather than being simply a technological gimmick, IPI is a different view of the way teaching should be done. IPI does not accept the view that every child should do exactly what he wants, which is not a necessary component of individualized instruction. IPI assumes that the ends are known, and it seems perfectly possible to define individualization of instruction in terms of a highly structured curriculum in which ends are stated behaviorally by somebody other than the student. Oettinger seems to criticize IPI because it does not meet his undefined criteria of what constitutes individualization.

American education does not have time, as Oettinger implies, to "fiddle around with both goals and techniques." If there is to be any future promise, new possibilities must be explored and developed now.

Reply, by Anthony G. Oettinger and Sema Marks, Harvard University

It is vitally important to distinguish between ultimate promise and immediate possibility. Also, one must avoid confusing a belief in the value of science with a belief that science necessarily has all the answers. Our critics show the influence of both kinds of confusion.

Persuasive pronouncements do reflect and induce in educational circles a significant body of prevailing opinion about educational technology. Especially if, as Becker states, people with money and power control the state of the schools, then the belief that technology can solve the educational problems of the inner city merits close examination. It is part of the national mood to expect a quick return on investments, but research results do not argue for massive implementation—only for further research.

We differ little with Suppes' statements. The main point is that only the drill and practice program can claim to be an important addition to current practice. That sales pitches transmute his work and that of others from ultimate promise to immediate possibility is precisely a consequence of the pressures for immediate return on investment.

In response to Glaser's faith in science, our point is merely that, as yet, behavioral sciences have provided little of immediate practical value. Further, his statement of the principal goal of education excludes drill and practice, so that even this technological advance is denied us. His argument that " . . . few have ever contended that the most easily measured products of education are necessarily the most valuable" is open to question. Finally, his modest and scholarly investigations have been federalized into a system whereby "the dropout problem would be largely licked."

In response to Bennis, it is not denying the possibility of future progress in social sciences to state that there is little here to aid the layman in his job of making decisions now.

If Becker is right on the devastating facts of current city schools, then the use of unproven educational technology as a placebo is dangerous indeed. The ultimate promise of educational technology must be sold on grounds other than those of immediate solution to problems in the inner city. Also, Becker's admission that goals and ends are set in IPI does class this experiment with techniques which we have called "mass production to narrow specifications with rigid quality control."

Ellis asks of us a sense of how technology can help determine what needs to be done. What needs to be done is a human problem. Technology only determines what can be done.

There is a disparity between the limitations of predictions based on a faith in science and the desire of those

who pay the bills to have something concrete to show for their money. The problem is not solved by scientists pretending to have the answers or by agencies funding "quickie" cures. In the absence of a single panacea, we must provide the flexibility needed to follow diverse paths toward knowledge and its useful applications.

Kopstein, Felix F. and Robert J. Seidel, "Computer Administered Instruction vs. Traditionally Administered Instruction: Economics," AV COMMUNICATION REVIEW, Summer 1968, 147-175.

This paper presents the "first attempt" at comparing the costs of Traditionally Administered Instruction (TAI) with Computer Administered Instruction (CAI). The assumptions used in arriving at the comparative figures are conservative, favoring TAI, since CAI involves "a developing technology without cost experience." Baseline assumptions include a 3-year life for an instructional program administered for a total of 4,224 student-hours (32 students per classroom for a 6 hour day for a 22 day month) for TAI. The cost/effectiveness analysis rests on the assumption of equal effectiveness for TAI and CAI. Cost data for TAI is fragmentary and often speculative; cost data for CAI, while not based on experience, is at least formed from orderly categories.

Costs of TAI

Three major categories of education are relevant: public elementary and secondary education, higher education, and military training. For public elementary and secondary education, data is available from the U.S. Office of Education (USOE) and the National Education Association (NEA). USOE figures are based on the average of states reporting instructional expenses over six categories: salaries for professional staff, salaries for clerical staff, textbooks, library books, teaching supplies, and miscellaneous expenses. NEA instructional cost figures, while based on unspecified categories, agree closely with USOE figures. The average cost per student-hour rose from 13c in 1949-50 to an estimated 33c in 1965-66. Individual districts vary around these figures. For example, in 1959-60 the average was about 22c while three cities reported spending 39c and one rural county spent 11c. USOE projections indicate an average cost per student-hour of 38c by 1970-71 and 42c by 1974-75.

USOE figures on the cost per student-hour for higher education rose from 37-46c in 1949-50 to 82c-$1.02 in 1963-64. The lower figures in each pair are based on the assumption of 800 classroom hours for an 11-month year, while the higher figures assume 640 hours over two semesters. The range of cost per student-hour for higher education is quite great. For 1957-58 the average cost was between 64-80c. For publicly controlled universities the range was 81c-$1.01 while it may have been as high as $1.93 in publicly controlled professional schools, or as low as 35c in publicly controlled junior colleges.

Estimates of the cost of military instruction per student-hour range from $0.006 (based only on the salaries of enlisted instructors) to $7.10 (for advanced, highly technical courses). Average costs are probably $1.80.

Costs of CAI

Five categories enter into consideration: computer hardware, maintenance and spare parts, CAI-related computer programing, instructional design, and administrative overhead. CAI costs will be the total costs in these categories distributed over the total number of student-hours the system is in use.

The "hardware" costs include the cost of data storage, the central processing unit (CPU), and the transmission of instruction to each student. The cost per student-hour depends on the degree of use given the system. The length of a TAI school day is limited by the availability of faculty, not students. CAI need not be constrained to a 6-hour day; a more reasonable assumption would be a 10-hour day plus 5 hours on Saturday, giving a 240-hour month as opposed to the 132-hour month for TAI. In the military it is not unusual for classes to run in three daily shifts from 6 a.m. to midnight. Assuming this, plus 9 hours on Saturday, we have a 432 student-hour month. Further, 3 additional hours per day might be added by taking advantage of time-zone differences.

Given these various estimates of usable time, the cost of some of the available hardware configurations can be calculated. For one medium-sized computer equipped with 32 cathode ray tube (CRT) student terminals, image projectors, and recorded message playing capability (IBM 1500 System), the rental cost per student-hour would be $3.63 (32 stations ⊠ 6 hours ⊠ 22 days), $2.04 (32 ⊠ 10 ⊠ 24) or $1.20 (32 ⊠ 18 ⊠ 24). A larger machine (DEC PDP-10), equipped with 448 teletypewriters as student terminals, would cost 50c, 28c, or 16c for each of the three breakdowns considered above.

Assuming a 20 man-year effort and a three-year effective life, the cost of programing the two computers mentioned above could range from 52c per student-hour for the IBM system (32 terminals ⊠ 10 hours ⊠ 24 days) to 2c for the DEC machine (448 terminals ⊠ 18 hours ⊠ 24 days).

Using unpublished data from H. H. Schaefer, an estimate

of $464 per month (over a 3-year life span) per instructional block is made for the cost of the instructional programs. This cost, when compared to hardware cost, is trivial, amounting to 6c per student-hour for the IBM configuration or .2c for the DEC system. Administrative costs are also a very minor factor.

CAI versus TAI

The provisory nature of the comparisons which follow cannot be overstressed. There is a basic and continuing need for analytic and comparative economic studies in education, especially in two areas: the value to society of increments in the breadth and depth of education, and the influence of varying rates with which these increments are brought about.

Based on the evidence that Programed Instruction (PI) is at least as effective as TAI, a conservative estimate that CAI (which is, at least, PI with "electronic page turning") and TAI are equally effective has been made. The cost of CAI cannot be a general average similar to the average TAI cost, but must be based on a CAI configuration appropriate to a given situation. In most of the situations considered, the CAI cost for hardware and maintenance would be the greatest item since cost for computer and instructional programs could be reduced to an insignificant level by widespread adoption.

Present CAI versus Present TAI

Assuming an elementary or secondary school context, the computer system with 32-station capacity could completely serve an average class. With present school policy, no more than 4,224 hours per month (32 stations ⊠ 6 hours ⊠ 22 days) would be used. A 1966-67 TAI cost estimate is 35-36c per student-hour. The CAI hardware cost alone for the same configuration would be $3.63. Add to this 1c for instructional material and 9c for the cost of a proctor, and a final cost of $3.73 indicates that CAI would have to be 10 times as effective as TAI to warrant its adoption. Even adding evening classes could not reduce this cost much below $2 per student-hour.

Higher education offers safer grounds for comparison. Assuming year-round use of the 32-station system, a hardware cost of $2.04 could be achieved. Since programing (computer and instructional) would be less widely distributed, 52c would be added for that and an additional 5c should be added for administrative costs, for a total of $2.61 per student-hour. If the current TAI cost of professional education were estimated to be $2.76 per student-hour (up from the 1957-58 figure of $1.93), that would give CAI a slight economic advantage.

If it is assumed that a university could take advantage of the larger CAI system, the cost per student-hour with 448 stations could be less than 75c. For suitable subject matter, then, the CAI student-hour cost is competitive throughout most institutions of higher education.

Educational versus Economic Considerations

CAI demands a careful "systems" approach and comparative economic indices do not support an immediate, hasty conversion to CAI. The only justification for any training method is its demonstrated capacity to produce improved student performance. CAI has the potential for adapting instruction to the individual student but there is no guarantee that the relevant decisions will be made. It must be remembered that it is the instructional process which will determine the efficacy of training–not the computer hardware or software.

Future CAI versus Future TAI

A more meaningful approach to the future is to consider how much CAI can be permitted to cost. To illustrate, let us assume that 10 major institutions are conservatively risking no more than the expected average TAI cost in 1970-71, or $1.40 per student-hour. With 100 stations at each institution, the permissible total cost per system is $3,780,000, or $37,800,000 for all 10 systems. Using our earlier estimates we have:

Software related to CAI language development over 10 years . . .	$1,116,000
Instructional Programing Costs	3,600,000
Course development.	7,200,000
Administrative Costs	1,420,000
Total	$13,336,000

This would leave $24,464,000 for hardware and maintenance. One-fifth of the remaining total would be set aside for maintenance (mostly on the student terminals). Terminals would cost about $5,000 each. With 10 per cent extra terminals, the cost for 1,100 would be $5,500,000. Computers (e.g., DEC PDP-10) would cost $400,000 to $450,000 per system and disk storage would add another $130,500 per system. This would leave a surplus of $8,260,000 from the total allowable cost, which could be used for needed research.

Teachers are in increasingly short supply. While the supply of instructional programers is also quite limited, the fact that fewer instructional programers can be used to reach more students implies that, in the long run, the supply of instructional programers is more likely to be adequate than the supply of teachers.

The main obstacle to the evolution of CAI lies in behavioral science questions of instructional strategy and tactics. Instructional programs for CAI are theories of instruction being empirically tested. Improvements derive directly from empirical data.

In the long run, costs can be expected to be so reduced that a cost per CAI student-hour of 11c, that spent by one rural district in 1959-60, is a probability.

Randall, Ronald and Charles Blaschke, "Educational Technology: Economics, Management and Public Policy," EDUCATIONAL TECHNOLOGY, June 30, 1968, 5-13.

Economics and Management

The new educational technology calls for an overhaul of traditional patterns of educational management. The first part of this article investigates the impact of educational technology on management of the schools.

Of the three sources of pressure influencing our educational institutions–politics, sociology and economics–it is the last which is dominant in the planning of facilities and in immediate school management. Further, economic considerations are an important characteristic of the new instructional tools.

Since they are expensive, the new tools may well have to rely on their ability to produce offsetting savings to win a place in the budget. Most school systems are not now able to conduct the type of economic analysis needed to demonstrate the benefits of markedly different educational technologies and methods of instruction. What is needed is a "functional accounting" which aggregates costs in terms of the operating factors or management decisions which affect them, and the functions they support, rather than in terms of funding sources or expense types.

The COST-ED Model, for evaluating Costs of Schools, Training, and Education, highlights the critical cost factors involved. Important aspects of the design scheme are "cost per unit student achievement" as a final summary statistic, division of resources consumed into enabling and operating categories, and identification of "opportunity costs." Three of the important economic considerations relevant to the new technology identified through the use of this model are discussed below:

1. Savings in learning time–One of the claims made for CAI is that it will reduce "learning time." Using cost data from the New York City high schools it was concluded that "savings in average time to learn through CAI will be by a significant margin its most fruitful source of economic justification." However, because using CAI without provisions for accelerating faster students through the school system is very costly, school management would be affected by the virtual abolishment of classroom patterns which hinder the progress of the faster student.

2. Full utilization of facilities–As the mix of resources employed in instruction changes from labor-intensive (teachers paid for time worked) to capital-intensive (equipment paid for whether used or idle), the economic pressures acting on the conduct of instruction changes dramatically. The ratio of maximum users to total served becomes crucial. The implication, again based on New York City data, is clear that doubly expensive school facilities could be supported if each were used by two full shifts of students. Tradition and the fact that capital cost represents only 20 per cent of total costs explain why the economic pressures for fuller scheduling have been ineffective. Staggering current users' schedules and attracting new users could lead to fuller utilization of facilities. For full scheduling, computer management becomes a requirement.

3. Free resources–A third finding is that the "free resource" of the time teachers now spend working after school would not be automatically recovered by the new technologies. How to recover this free resource is an unsolved problem.

Given the argument that management changes must come with technological innovations, the question of which comes first arises. It is the management changes which must lead the way.

Implications for Public Policy

The COST-ED Model illustrates a major problem in public education of inadequate management and lack of "efficiency thinking."

Program planning and budgeting capabilities need to be developed on both state and local levels. Through such management tools as "sensitivity" and "trade-off" analyses developed in the COST-ED model, better questions on alternatives can be asked to justify them.

At the federal level, there should be more funding of total packages and large scale projects to encourage better management. Further, more funds for computer-managed instruction (CMI), rather than computer-assisted instruction, should be allocated. Based on the results of the COST-ED model, CMI must be developed before CAI can be fully utilized.

Creating an Environment Conducive to Change

There should be more projects designed to break the 200-year-old, inefficient monopoly of public education. Without competition, it is folly to believe public education will reform itself.

Greater priority needs to be given to the development of achievement criteria and assessment methods. A large "hard" data base needs to be developed, again calling for more work in CMI.

Teacher resistance to innovation might best be solved through rewarding classroom "managers of the conditions of learning" for effective work.

Uncertainty about the social and political impact of capital-intensive instruction must be reduced. The local politics of education is most important when costly and controversial innovations such as CMI and CAI are concerned.

General Learning Corp., COST STUDY OF EDUCATIONAL MEDIA SYSTEMS AND THEIR EQUIPMENT COMPONENTS. VOL. III. A SUPPLEMENTARY REPORT: COMPUTER ASSISTED INSTRUCTION, Washington, D.C., 1968.

A managerial tool for evaluating the cost-effectiveness of instructional systems–particularly CAI–is presented. This is needed to improve control, assist in decision-making and provide a sound planning basis for the instructional process. To this end a "Costs of Schools, Training, and Education" (COST-ED) model has been developed.

The objectives of the model include identification of the important factors, and the relationships among these factors, with applicability to all media and situations. The model itself consists of a pattern of cost factor definition and aggregation, the mathematical relationships among these factors, and procedures for using the information in decision-making. Some of the questions the model addresses itself to are: How sensitive are summary costs to various factors? What are the trade-offs between consumed resources? and What are the opportunity costs of management actions not taken? To accomplish the purpose of the model with flexibility, it has been made as general as possible and has been constructed of modular subsets of cost factors. Because of this, the proper use of the model may require translation of available cost data from its source format into the model format.

The conceptual scheme employed views the instructional process as one which supports and controls interaction or communication between sources of knowledge (the curriculum) and the learner. This process may be described by functions performed, enabling resources required, and operating resources consumed.

Functions performed can be divided into those immediately a part of the instructional process ("instruction") and those which support or provide non-instructional services to the learner ("student support"). Instruction activities involve teachers, textbooks, classrooms–all more or less directly affecting student achievement. Student support activities involve school buses, attendance control, health services–activities which do not directly affect achievement and are utilized only so long as instruction is performed.

Enabling resources are required for the performance of a function but, like school buildings, they exist and may depreciate whether that function is performed or not.

Operating resources are consumed only when utilized as a function of time (e.g., teacher effort) or unit volume (e.g., textbooks).

Design Scheme for the COST-ED Model

Activities begin with the definition of the process to be used rather than with the statement of an existing process. The first step is the identification of the functions to be performed. Then the teacher time use and student flow patterns are determined. Requirements for enabling resources are established, charge functions for various cost components are figured and, finally, costs per unit of student achievement are identified.

Each COST-ED model module consists of a formula which relates several cost factors and shows how detailed factors are used to calculate summary cost statistics of interest. Each module can be summarized by the functions it performs and the types of applications to which it is suited.

The Final Summarization Module performs the last combining calculations needed to develop total cost per unit student achievement and total educational/training costs per unit time. It can be used without support from other modules to combine gross estimates of a minimum number of cost factors into the summary statistics noted. It can also be used with the other modules to develop detailed calculations of these statistics.

The Manpower Requirements Module calculates the number of students required at any time to produce required per unit achievement. It also calculates the per unit achievement required to support the training activity. It allows the effect of changes in training time to be evaluated. It can be used in military settings where the trainee is available for fixed time, or in organizations where manpower time is divided between production and training. More broadly, it can be used to analyze educational costs where a lifetime is split between education and training, and there are fixed national requirements for a given occupation.

The Attrition Module corrects other factors for the effect of student attrition and recycling, and can be used where this is a significant factor.

The Teacher Module calculates the teachers required and relates the manner in which teacher's time is used to instructional costs, recognizing the effect of the teacher-student ratio on costs. It can also be used to calculate cost of unpaid teacher effort which represents "free resources" contributed by teachers.

The Facilities Requirement Module is described in terms of a specific facility in the sense of an "enabling resource" rather than in terms of specific cost factors. Facilities are divided into "equipment" (associated with one function) and "housing" (which may serve several functions). This module can be used to calculate the size or number of facilities needed to support a given function and to identify the opportunity costs of not making use of available facilities. It may be used in situations where facility costs are significant and to calculate the cost effects of changes in usage of facilities.

The Student Opportunity Cost Module provides a means for calculating any cost variable with student time not

considered elsewhere in the model, or the income lost by a student while under full-time instruction. It may be used where evaluation of changes in student achievement are analyzed against the cost of alternative student activities. For example, it could be used to evaluate the effect on gross national product of shortening elementary and secondary education to 11 years.

How the complete model is used depends on the application and the user involved. How the modules are combined, and which are used, may vary.

Justification of Increased Instructional Facilities

This section provides examples of how the model may be used for sensitivity and trade-off analysis. The examples are framed within the context of justifying increased facilities costs through economies elsewhere, since this application is most relevant to CAI.

A New York City Academic High School is used in this example of applying the COST-ED model:

Assuming the approximate validity of the statistics generated by working backwards in the model rather than from very basic costs, the model shows that teachers contribute $36 million a year in free time, that $32 million a year is spent supporting facilities not in use, that almost all costs are time dependent and therefore affected by a reduction in time required to complete a unit of achievement, and that one-quarter of total costs are incurred in student support not directly related to achievement-producing instruction.

A "sensitivity analysis" leads to some additional conclusions. Instructional facilities utilization costs are highly sensitive to their peak usage factor. Total costs per unit of student achievement are not very sensitive to changes in the facilities utilization cost factor. By flattening peak requirements, then, instructional facilities cost increases can be reduced.

"Trading-off" dollar investment in CAI per student against various factors related to teacher costs points out that savings in average annual teacher costs is the second strongest source of justification for CAI equipment investment. Savings in time per unit achievement is the strongest source.

As conclusions from the application of the COST-ED model to the justification of investment in CAI facilities in New York's academic high schools, the following is stated:

1. A 20 per cent reduction in time to learn would occur.
2. Average teacher costs would be reduced 10 per cent.
3. A peak usage of no more than 50 per cent of the students would be needed.
4. There would be justification for an investment of about $3,720 per student enrolled.

The COST-ED model only provides a simple framework for the analysis of economic factors; it is up to CAI developers to determine whether the reductions and savings are within the psychological and technical capabilities of CAI.

Cost Considerations for CAI

One of the major differences between CAI and more traditional methods of instruction is the relatively higher use made of enabling resources in comparison with operating resources. It is worthwhile here to develop more detailed economic relationships for considering the enabling resources component of CAI.

It is difficult, and therefore hazardous, to be too specific about hardware configurations required by CAI. The approach taken here is patterned after that taken by the COST-ED model as a whole–the definition of cost factors on the basis of functions performed–since it avoids dependence on specific hardware configurations. Three major functions are performed by hardware: instructional process control (performed by the decision-making components of the system), curriculum availability (performed by storage devices), and student-system communication (performed by input-output devices).

The advantages of this sort of breakdown of functions are that trade-offs between items of equipment which perform the same function are more easily seen, costs can be related to readily available indices such as "costs per instruction executed" or "cost per data bit stored," and cost-effectiveness relationships may be formulated using such factors as "cost per function per student-hour."

Applying this tri-function approach requires a method for distributing the costs among the three functions for each configuration considered. Using this approach to evaluate competing equipment proposals would involve analyses of the "growth" capability and "balance" in usage among components of the system. In addition, cost-per-function would be analyzed in terms of differences in system design and hardware capability.

A key characteristic of CAI equipment configurations is the sharing of central equipment by many pieces of end-user equipment. With "clustering," many levels of centralization may be used. This leads to various apportionings of costs to the individual user based on the degree to which the central facilities are shared. By far the largest component of cost per student is likely to be tied up in the student terminal. The system with lower student terminal costs will have an economic advantage as usage expands.

In addition to equipment, CAI requires large investment in the development of instructional programs. The "software" required can be divided into "machine language" (that used to program the computer itself), "instructional programing language" (used to program curriculum materials), "CAI curriculum materials" and "student/system communication language."

It appears that the largest component of costs in CAI curriculum development would be for personnel. Current estimates are that 200 man-hours are required to convert one hour of classroom instruction to CAI format. Factors which influence the amount of effort include definition of learning objectives, systematization of programing procedures, dimensionality of student error possibilities, and refinement of style in the CAI program.

Although there are similarities betwen the economics of textbook authoring and those of CAI program authoring, thus far there have been no "unit" sales of CAI curriculum materials upon which to base costs. The continual modification of CAI programs by users also confuses cost analyses. Unlike buildings, CAI programs may never be replaced or abandoned,

and this makes finding an appropriate basis for amortization of developmental costs very difficult.

The All-or-Nothing Effect

Because of the large differences between the economics of CAI and classroom instruction, CAI cannot be economically justified as an additive to the regular classroom but must become the dominant pattern. It would be economic folly to allow CAI to be misused in the same way that instructional television and programed instruction have been misused–the first by not reducing classroom instructor costs when the television is in use; the second, by fitting the programed instruction booklet use into fixed-length class periods. With CAI, the economics more forcefully cry out for all-or-nothing application.

Conclusions from Economic Analysis

The first applications of CAI will be in military and welfare settings, with public schools waiting until costs fall. CAI will be used far more than for a normal 40-hour working week. Development of a programing language usable by minimally trained personnel, and the adaptability of administrations to individualized scheduling of learning, are needed to promote wide public school use. The "All-or-Nothing Effect" is relevant to this point.

Significance of Guidelines for CAI

The high costs of CAI research and development necessitate guidelines which must take into account the fact that CAI can both instruct and aid in research on instruction. Guidelines can help in communication between sponsor, contractor and user, and they can communicate the relative priorities of the efforts.

The existing major problems in CAI are identified as:

1. Public policy has been inadequate to ensure timely development and testing. This has come from a failure to communicate priorities to the politically responsible officials. It has resulted in much duplication and wasted effort.

2. CAI has not been made legitimate. Working programs have not been published. Other than for drill and practice, CAI is talked of as very experimental.

3. The average size of CAI projects tends to be too small for effective work. Only a few projects have been funded at a size sufficient to produce effective results.

4. Efforts at cost effectiveness studies have been premature. Until criteria based on learning performance standards are developed, little can be gained from attempts to evaluate the cost of CAI.

5. "Demonstration" clauses under which much of the work has been federally funded have not been taken to mean demonstrated "effect," and thereby the diffusion of the technique, but have been interpreted as implying "value"–simply showing that the project worked.

6. Skilled manpower to produce quality research in education and to produce capable program management has been in short supply.

7. Guidelines for support and expansion of experimental programs have not been developed.

The guidelines included in this report are intended to aid potential contractors in submitting rationally evaluatable proposals to the USOE. CAI will develop, like most technologies, through three phases: applied research, development in workable systems, and demonstration of "value" and "effect." The priorities which are of greatest importance to USOE include increasing the effectiveness of instruction, developing criteria for measuring the effectiveness of CAI, developing flexible management systems which will help realize the cost savings resulting from CAI, and providing an opportunity for community participation in planning or evaluation.